DECOMPOSITION OF *PINUS RADIATA* LITTER ON THE FOREST FLOOR

Part 2. CHANGES IN MICROFAUNA POPULATION

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Summary

Insect population changes in *Pinus radiata* D.Don, needle litter during breakdown were examined over four years from July 1960 to December 1964. The litter samples were in 1 mm mesh nylon bags on the forest floor. All microfauna (including mesofauna) were extracted from litter samples periodically and where possible, identified. The number of specimens was highest in 1962–63 and then decreased rapidly until final examination in December 1964. The pattern of species changed with the progress of litter breakdown. During the first two years Collembola, small beetles and lepidopterous larvae were well represented together with a few species of Hemiptera and Diptera, and predatory and omnivorous mites. In the third year omnivorous mites, especially the Oribatei, increased markedly. By the fourth year the samples were well covered with litter and adventitious growths; the microfauna population had decreased. Because the 1 mm mesh bags limited the range of soil fauna with access to the samples, litter breakdown inside the bags was not as advanced as that of natural litter at the end of the experiment.

INTRODUCTION

In this investigation the microfauna* population changes and their effect on decomposition of radiata pine needle litter were studied over four years.

Grimmett (1926) gave one of the first comprehensive accounts of microfauna in New Zealand native beech and tawa forest litter. Other entomologists have collected various species of macro- and microfauna from both alpine and lowland forest litter sites since then. Species which assist breakdown of litter in both indigenous and exotic forests include earthworms, tipulid larvae, bush-hoppers (K. W. Duncan, pers. comm.) and woodlice (F.R.I. unpublished records 1960–1966); springtails (Salmon, 1941, 1964), millipedes (Dawson, 1958; Johns, 1962), oribatid mites (Ramsay, 1962; Hammer, 1966 and pers. comm.) and lepidopterous larvae (F.R.I. unpublished records). Womersley (1936) and Wood (1964) have studied the importance of predatory mites. Cumber (1959) has studied ants and laboratory observations have been made on predatory anthocorid bugs (Styles, 1962).

*The term microfauna in this paper includes the mesofauna.

Overseas, extensive investigations have been made into microfauna associated with litter breakdown in conifer forests (Kühnelt, 1961; Lawrence, 1953; McE. Kevan, 1962).

TECHNIQUES

Gilbert and Bocock (1962) and Crossley and Hoglund (1962) have discussed the use of 1 mm and 1 cm mesh nylon bags in their Northern Hemisphere experiments on microfauna associated with litter breakdown in hardwood and softwood stands.

The 1 mm mesh of the nylon bags used in the present study (Will, 1967) restricted movement of larger soil fauna such as earthworms, ground beetles, bush-hoppers, tipulid larvae, woodlice, slugs and snails which would have accelerated decomposition. Juvenile dipterous and lepidopterous larvae, mites, centipedes and millipedes were able to pass through the nylon mesh and complete their development in the contained samples.

The bags containing litter samples, on their removal from the experimental site (Will, 1967, Fig. 1) were examined externally for moss and other plant growth before the litter was removed. Notes were made on the moisture content, state of decomposition, fungal development, plant rootlets penetrating the litter and other relevant details.

The samples were placed separately on a sheet of perforated metal in 10 in. berlese-type funnels directly under a fluorescent light strip and the microfauna extracted into beakers containing 90% alcohol. The samples remained under the light strip from four to five days until dried out.

Specimens were classified and, after counting, were either mounted or placed in preservative solution, labelled and catalogued. At the end of each season a list giving the total number of each species in the samples was compiled.

RESULTS AND DISCUSSION

(A summary of specimens extracted from the samples in each year is given in Tables 1–4.)

First Year Collections, September 1960 – July 1961

From the first two collections in September and December, before the pine needles had begun to break down appreciably, large numbers of Collembola, one Hemiptera species (Miridae) and very small trichopterygid beetles were extracted. These insects would at first have been feeding on the soft epidermis of the needles and later on the decomposing litter. By March some of the needles had become matted with small patches

of fungal mycelia and about this time the number of entomobryoid Collembola decreased considerably.

In July some of the samples had moss, algae, and *Nertera depressa* growing on the upper surface of the bags. Throughout the first year the number of both predacious and omnivorous mites was very low.

Fauna extracted ranged from 0.5 mm to 6 mm in length.

Second Year Collections, October 1961 – June 1962

By the second year all samples contained broken down needles with patches of matted needles and fungal mycelia. Small plant rootlets were beginning to penetrate the needle litter. In hot weather the surface layers of samples dried out to a certain extent, except where small plant seedlings and fallen needles, which partly covered some of the samples, helped to retain moisture.

By December most samples contained needles which were being slowly broken down by insect and other arthropod feeding and by fungal mycelia. From March lepidopterous larval frass was observed. Hypogastruroid springtails were present though fewer than in the first year; the number of entomobryoid species had decreased considerably; trichopterygid beetles remained numerous. Predacious and omnivorous mites increased slightly in number; lepidopterous larvae together with a few juvenile millipedes and symphylids were collected.

Fauna extracted ranged from 0.5 mm to 10 mm in length.

Third Year Collections, September 1962 – July 1963

By the third year the bags had become generally covered with a layer of pine litter, other debris, or patches of moss and small plant seedlings. Fine rootlets of the latter penetrated into the samples.

Insect and other arthropod species collected in the samples changed from the 1960 pattern. There was a marked decrease in the number of Collembola, staphylinid and trichopterygid beetles; there was a gradual increase in the number of omnivorous mites, particularly species in the suborder Oribatei (oribatids) which are very important in the breakdown of organic matter, more especially after preliminary breakdown by insect larvae and other arthropods. Hemiptera were absent.

Predatory mites were fewer except for gamasid and trombidiid species; only a few dipterous and lepidopterous larvae were collected.

Fauna ranged from 0.25 mm to 16 mm in length.

Fourth Year Collections, December 1963 – December 1964

By the fourth year nearly all the bags had become well covered with a layer of needle litter and other debris.

TABLE 1—Summary of Specimens Extracted in the First Year

FAUNA	1960		1961		Total	Remarks
	7/9	8/12	21/3	6/7		
Collembola. Springtails						
Arthropleona : Hypogastruroidea	*⩾76	21	19	13	⩾129	*Very common in sample
,, : Entomobryoidea	*⩾80	*75	42	24	⩾221	* ,,
Symphypleona	4	–	–	–	4	Black sp. 0·5–1 mm
Hemiptera : Heteroptera						
Miridae – Adults	3	1	1	3	8	Plant bugs
,, – Nymphs	–	10	9	5	24	
Anthocoridae – Adults	1	–	–	–	1	*Cardiastethus consors* B. White—predatory anthocorids
,, – Nymphs	7	–	–	–	7	
Coleoptera : Staphylinidae	9	7	1	–	17	Adult Rove beetles 2–5 mm
,, : ,,	20	–	6	20	46	Larvae
,, : Trichopterygidae	11	29	15	72	127	Adults 1–2 mm
,, : Pselaphidae	–	6	6	6	18	Adults 1–3 mm
,, : ?Scydmaenidae	–	2	–	–	2	Adults
,, : Unidentified sp.	–	1	–	–	1	Small predatory larva
,, : ,,	–	–	–	1	1	Larva
Psocoptera (Copeognatha) – Nymph	–	–	1	–	1	Bark and debris lice

Diptera : Cecidomyidae – Larva	–	3	–	1	4	Gall midges
,, : Unidentified sp.	–	–	1	–	1	Larva
,, : Ceratopogonidae	–	–	–	1	1	Midges. Larva
Lepidoptera : Oecophoridae – Larvae	–	–	8	2	10	*Borkhausenia* sp.
Araneida. Spiders	–	–	7	2	9	Juvenile.
Acarina. Mites						
Bdellidae. Snout mites	1	1	2	*⩾60	⩾ 64	*Predacoius nymphs very common in sample
Anystidae. Anystid mites	–	3	–	–	3	Predacious
Trombidiidae. Trombidiid mites	–	–	4	–	4	,,
Eupodidae. Eupodid mites	4	–	–	7	11	Predacious *Linopodes* sp. (D.E.J.)
Gamasidae (Parasitidae)	–	–	8	1	9	Predacious and omnivorous
*Oribatéi : Oribatidae	⩾30	1	5	–	⩾ 36	*Oribatid mites
,, : Achipteriidae	–	–	–	15	15	New genus, new species (G.W.R.)
,, : Phthiracaridae	–	–	1	–	1	
,, : Camisiidae	–	–	1	–	1	
Diplopoda. Millipedes	–	–	*3	7	10	**Siphonethus* sp. juvenile (P.M.J.)
Turbellaria. Land planarians	–	–	1	–	1	
Mollusca. Snails	–	–	2	2	4	Minute sp. 1 mm diam.

*Figures for each date are an aggregate of three litter samples.

TABLE 2—Summary of Specimens Extracted in the Second Year

FAUNA	1961		1962		Total	Remarks
	12/10	21/12	14/3	27/6		
Collembola. Springtails						
Arthropleona : Hypogastruroidea	9	14	4	10	37	7 species
,, : Entomobryoidea	19	*⩾40	1	–	⩾60	*Common in sample
Hemiptera : Heteroptera						
Miridae – Adults	1	5	1	–	7	Plant bugs
,, – Nymphs	8	7	10	–	25	
Coleoptera : Staphylinidae	4	3	3	–	10	Adult Rove beetles 2–5 mm
,, : ,,	2	7	7	1	17	Larvae
,, : Trichopterygidae	46	18	3	17	84	Adults 1–2 mm
,, : Pselaphidae	1	3	–	–	4	Adults 1–3 mm
,, : Carabidae	2	–	–	–	2	Unidentified larvae
Psocoptera (Copeognatha)						
Caeciliidae – Dead adult	–	–	–	1	1	Psocids, bark lice
Diptera : Tabanidae	4	1	2	5	12	Larvae 3–5 mm
,, : Cecidomyidae	1	–	–	–	1	Larva
,, : Sciariinae	–	–	1	*1	2	*Pupa
,, : Empididae	–	–	1	–	1	Larva
,, : ?Thaumeleidae or Ceratopogonidae	–	–	–	2	2	Larvae
,, : Unidentified spp.	–	1	–	–	1	Adult
,, : ,,	–	1	2	1	4	Larvae
,, : ,,	–	2	–	–	2	Puparia

Lepidoptera						
Oecophoridae – Larvae 1–5 mm	7	1	3	5	16	*Borkhausenia* sp.
,, – hatched pupae	–	–	–	2	2	
Araneida. Spiders	1	5	4	1	11	Juvenile specimens
Acarina. Mites						
Trombidiidae. Trombidiid mites	–	⩾30	7	–	⩾37	Nymphs
,, ,,	–	–	3	1	⩾ 4	Adults
?Eupodidae. Eupodid mites	–	–	1	–	1	Nymph
Gamasidae (Parasitidae)	–	1	1	3	5	Nymphs
Oribatei : Oribatidae	5	3	3	–	11	Large % nymphs
,, : ,,	4	–	–	–	4	New genus. New species (M.H.)
Unidentified species	–	⩾30	–	–	⩾30	Nymphs
Diplopoda : Millipedes	–	–	–	1	1	Juvenile Julid specimen
Polyzoniidae	–	–	1	1	2	?*Siphonethus* sp. Juvenile
Chilopoda. Centipedes	3	–	1	–	4	Unidentified juveniles
Symphyla. Symphylids	4	1	1	1	7	Large % juvenile
Mollusca. Snails	3	2	1	1	7	1–2 mm diam

*Figures for each date are an aggregate of three litter samples.

TABLE 3—Summary of Specimens Extracted in the Third Year

FAUNA	1962		1963		Total	Remarks
	26/9	24/12	21/3	11/7		
Collembola. Springtails						
Arthropleona : Hypogastrutoidea	8	11	3	10	32	4 species
,, : Entomobryoidea	–	–	2	3	5	3 species
Coleoptera : Staphylinidae	1	5	–	–	6	Adult Rove beetles 2–4 mm
,, : ,,	4	2	4	4	14	Larvae
,, : Trichopterygidae	8	14	2	9	33	Adults 1–2 mm
,, : Pselaphidae	1	–	–	1	2	Adults 1·75 mm
,, : Byrrhidae	–	–	1	–	1	Adult 1 mm
,, : Unidentified sp.	–	–	–	1	1	Larva 2 mm
Psocoptera (Copeognatha) : Troctidae	–	1	–	–	1	Bark and debris lice
Diptera : Cecidomyidae	–	–	5	–	5	Adults
,, : ,,	–	–	*1	7	8	Larvae 1–1·5 mm, *puparium
,, : ?Empididae	2	–	–	–	2	Juvenile larvae
,, : Tabanidae	–	1	–	3	4	Larvae 2–11 mm
,, : Unidentified sp.	–	2	2	–	4	Larvae 1–6 mm
,, : ,,	–	1	–	–	1	Puparium 2 mm

Hymenoptera : Unidentified sp	–	–	–	1	1	Free pupa
Lepidoptera						
Oecophoridae – larvae 2–5 mm	3	–	–	6	9	*Borkhausenia* sp.
Araneida. Spiders	–	1	–	2	3	Juvenile specimens 3–4 mm
Acarina. Mites						
Trombidiidae. Trombidiid mites	6	4	1	–	11	Nymphs
,, ,,	1	3	1	6	11	Adults
Gamasidae (Parasitidae)	–	30	7	73	110	Very juvenile to mature nymphs
Oribatei : Oribatidae	2	6	–	37	45	Unidentified sp. Large % nymphs
,, : Camisiidae	–	–	–	37	37	Nymphs 0·5 mm
,, : Phthiracaridae	–	5	4	23	32	Large % nymphs
Unidentified species	2	1	4	5	12	
Diplopoda. Millipedes						
Unidentified sp.	–	–	–	1	1	Juvenile specimen
Polyzoniidae	4	–	–	1	5	Juveniles 2–5 mm
Chilopoda. Centipedes						
Zelanion sp.	2	–	–	–	2	
Symphyla. Symphylids	–	5	–	1	6	2–4 mm

*Figures for each date are an aggregate of three litter samples.

TABLE 4—Summary of Specimens Extracted in the Fourth Year

FAUNA	1963	1964		Total	Remarks
	5/12	10/6	8/12		
Collembola. Springtails					
Arthropleona : Hypogastruroidea	2	2	3	7	2 species
Coleoptera					
Staphylinidae. Rove beetles	4	1	–	5	Adults 2–3 mm
Carabidae. Ground beetles	–	2	–	2	Larvae 0·5–2 mm
Pselaphidae	1	–	–	1	Adult 1·5 mm
Cryptophagidae. Fungus beetles	3	–	–	3	Adults 1·75–2 mm
Curculionidae. Weevils	–	1	–	1	Larva 1·5 mm
,,	–	–	1	1	Pupa 2 mm
Psocoptera (Copeognatha)	–	–	1	1	Nymph. Bark and debris lice
Diptera					
Tabanidae. March & Horse flies	1	–	1	2	Larvae 5–8 mm
Cecidomyidae. Gall midges	–	–	1	1	Larva 1 mm

Lepidoptera					
Oecophoridae	1	–	1	2	*Borkhausenia* sp. Larvae 5–8 mm
Araneida. Spiders	–	1	1	2	Juvenile specimens 2–3 mm
Acarina. Mites					
Gamasidae (Parasitidae)	2	6	9	17	2 Adults, remainder nymphs
Oribatei : Oribatidae	5	6	9	20	With no pteromorphae (wing pads) 0·5 mm
,, : ,,	2	2	10	14	With pteromorphae 0·5–1 mm
,, : Camisiidae	2	3	–	5	Nymphs 0·5 mm
,, : Phthiracaridae	8	3	–	11	,,
Unidentified sp.	–	–	1	1	Nymph
Symphyla. Symphylids	1	3	1	5	Juvenile specimens 1–2 mm

*Figures for each date are an aggregate of three litter samples.

TABLE 5—Summary of Seasonal Population Changes of Fauna Extracted from Needle Litter Samples

FAUNA	1960			1961				1962				1963			1964
	7/9	8/12	21/3	6/7	12/10	21/12	14/3	27/6	26/9	24/12	21/3	11/7	5/12	10/6	8/12
Collembola. Springtails															
Arthropleona : Hypogastruroidea	*	X	X	†	†	†	†	†	†	†	†	†	†	†	†
,, : Entomobryoidea	*	*	X	X	†	X	†				†	†			
Symphyleona	†														
Hemiptera : Heteroptera															
Miridae. Plant bugs	†	†	†	†	†	†	†								
Anthocoridae. Predatory bugs	†														
Coleoptera															
Staphylinidae. Rove beetles	X	†	†	X	†	†	†	†	†	†	†	†	†	†	
Trichopterygidae	†	X	†	*	X	X	†	X	†	†	†	†			
Pselaphidae		†	†	†	†	†			†			†	†		†
Carabidae. Ground beetles					†									†	
Cryptophagidae. Fungus beetles													†		
Curculionidae. Weevils														†	†
Psocoptera (Copeognatha). Psocids			†					†		†					†
Diptera															
Cecidomyidae. Gall midges		†		†							†	†			†
Ceratopogonidae. Midges				†	†			†							
Sciariinae. Fungus–gnats							†	†							
Empididae							†		†						
Tabanidae. March & Horse flies					†	†	†	†		†		†	†		†

*Very common. X Common in samples. † Present in small numbers.

TABLE 5—*continued*

FAUNA	1960		1961			1962						1963		1964	
	7/9	8/12	21/3	6/7	12/10	21/12	14/3	27/6	26/9	24/12	21/3	11/7	5/12	10/6	8/12
Lepidoptera : Oecophoridae			†	†	†	†	†	†	†			†	†		†
Araneida. Spiders			†	†	†	†	†	†		†		†		†	†
Acarina. (i) Predatory mites															
Bdellidae. Snout mites	†	†	†	*											
Anystidae. Anystid mites		†													
Trombidiidae. Trombidiid mites			†			X	†	†	†	†	†	†			
Eupodidae. Eupodid mites	†			†			†								
Gamasidae (Parasitidae)			†	†		†	†	†		X	†	*	†	†	†
(ii) Omnivorous mites															
Oribatei : Oribatidae	X	†	†		†	†	†		†	†		X	†	†	X
,, : Archipteriidae				†											
,, : Phthiracaridae			†							†	†	X	†	†	
,, : Camisiidae			†									X	†	†	
Diplopoda. Millipedes			†	†				†	†			†			
Chilopoda. Centipedes					†		†		†						
Symphyla. Symphylids					†	†	†	†		†		†	†	†	†
Mollusca. Snails			†	†	†	†	†	†							

* Very common. X Common in samples. † Present in small numbers.

Between May and December there was a marked decrease in insect and other arthropod species in the samples; the number of Collembola and staphylinid species was considerably lower than in the previous year; both Hemiptera and trichopterygid species were absent; only two lepidopterous larvae (Oecophoridae) which feed on needle litter were collected although frass was observed; there was a marked decrease in numbers of both predacious and omnivorous mites, especially the Oribatei.

Fauna ranged from 0.25 to 11 mm in length.

CONCLUSIONS

Over the four-year period, July 1960 to December 1964, the population pattern of microfauna species extracted from radiata pine litter changed according to the type of food material available, agreeing with observations of overseas workers.

Collembola were well represented in the first year before breakdown of the pine needles began, while omnivorous mites, especially the Oribatei, were well represented in the third year.

Only small species or juveniles of larger species were able to pass through the 1 mm mesh of the nylon bags. Some species, e.g., dipterous and lepidopterous larvae and mites, completed their development inside the bags but were unable to emerge through the fine mesh and migrate to other areas in the forest litter.

Once the bags had been well covered with pine needle litter and other debris, there was a marked decrease in both insect and other arthropod species.

After 4 years, litter in the bags had not decomposed as much as that lying naturally on the forest floor (Will, 1967, Fig. 5), indicating that macrofauna excluded by the fine mesh would normally have continued breakdown beyond the stage achieved by microfauna.

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APPENDIX I

List of Identified Specimens Extracted From the Litter Samples

HEMIPTERA – HETEROPTERA

Family: ANTHOCORIDAE.
Cardiastethus consors B. White.
Common in pine litter (F.R.I. records).
1 adult, 7 nymphs, 1960–1.

COLEOPTERA

Family: CRYPTOPHAGIDAE.
Cryptophagus sp.
3 adults, 1963–4.
Family: PSELAPHIDAE.
Anabaxis euplectoides Broun (Det. E.S.G.).
10 adults, 1960–1; 4 adults, 1961–2; 1 adult, 1962–3 and 1 adult, 1963–4.
Family: STAPHYLINIDAE (Det. W.O.S.).
Atheta n. sp. 1 (near *splendidicollis* Bnh.).

3 adults, 1960–1.
Atheta n. sp. 2.
2 adults, 1961–2.
Oxytelus sp.
Unlikely to be new, probably Australian. All the New Zealand *Oxytellus* appear to be introduced.
1 adult, 1960–1.
Oxytelus piceicollis Fvl.
Australian species, not previously recorded from New Zealand.
1 adult, 1960–1.
"*Tachyusa*" *fuscicornis* Broun.
5 adults, 1960–1; 2 adults, 1961–2.

LEPIDOPTERA

Family: OECOPHORIDAE.
Borkhausenia sp.
B. armigerella Walk., common in pine litter (F.R.I. records).

ARACHNIDA – ARANEIDA

One common species found in *Pinus radiata* litter is *Diplocephalus cristatus*, a small black spider often found in grassy areas, introduced from Europe (pers. comm., R. R. Forster).

ACARINA

PROSTIGMATA (s. lat.) or TROMBIDIFORMES.
Family: EUPODIDAE.
Linopodes sp. (Det. D.E.J.).
11 specimens, 1960–1.
Family: BDELLIDAE.
Bdella and *Bdellodes* species, common in pine litter (pers. comm., W.T.A.).
Nymphs very common in samples, 1960–61.
SARCOPTIFORMES
ORIBATEI.
Family: ACHIPTERIIDAE.
Notachipteria cuspidata n.g., n.sp. (Det. G.W.R.).
15 specimens, 1960–1.
Family: CAMISIIDAE.
Acronothrus species.
1 adult, 1960–1; nymphs common in samples, 1962–3.
Superfamily: CERATOZETOIDEA.
Parahypozetes macrodentatus n.g., n.sp. (Det. M.H.).
4 specimens, 1961–2.

DIPLOPODA

Family: POLYZONIDAE.
Siphonethus sp.
Juveniles. 3 specimens, 1960–1; 1 specimen, 1961–2.